IBM Dictionary of Computing, McGraw-Hill, 1994.

Appendix 1

video Pertaining to the portion of recorded information that can be seen.

video black In video presentations, the absence of pictures and sound, usually at the beginning and end of a program and between segments.

video board Synonym for graphics adapter.

videocassette recorder (VCR) A device for recording or playing back videocassettes.

video clip A section of filmed or videotaped material.

videoconferencing Teleconferencing that provides transmission of still or moving images, in addition to voice, text, and graphics. (T) See also conference call, teleconferencing.

video digitizer Any system for converting analog video material to digital representation.

videodisc A disc on which programs have been recorded for playback on a computer or a television set; a recording on a videodisc. The most common format in the United States and Japan is an NTSC signal recorded on the optical reflective format.

videodisc player In multimedia, a device that provides video playback for prerecorded videodiscs.

video display terminal (VDT) (1) A user terminal with a display screen, and usually equipped with an input device such as a keyboard. Synonymous with visual display unit (VDU). (T) (2) In SAA usage, deprecated term for display device.

video display unit (VDU) (1) Synonym for visual display unit. (2) In SAA usage, deprecated term for display device.

video encoder A device that transforms a high-resolution digital image from a computer into a standard television signal, thereby allowing the computer to create graphics for use in video production.

video gain The strength of a video signal.

video graphics adapter (VGA) A computer adapter that provides high-resolution graphics and a total of 256 colors. See enhanced graphics adapter (EGA).

video head The mechanism inside a videotape player that reads the video information recorded on the tape.

video lookup table (VLT) A color map implemented in hardware.

video monitor A display device capable of accepting a video signal that is not modulated for broadcast either on cable or over the air. In videotaping, a television screen on which the footage can be viewed as it is being recorded.

video scan converter A device that emits a video signal in one standard into another device of different resolution or scan rate.

video segment A contiguous set of recorded data from a video track. A video segment may or may not be associated with an audio segment.

videotape (1) A tape used to record visual images and sound. (2) In multimedia applications, a recording of visual images and sound on magnetic tape. All shooting is done in this format, even if the results are later transferred to videodisc or film. (3) To make a videotape.

videotape formats See one-inch videotape, three-quarter-inch videotape, half-inch videotape, eight-millimeter (8mm) videotape.

videotape recorder (VTR) A device for recording and playing back videotapes.

video terminal paging An IMS/VS facility that allows the application programmer to send multiple screens of information to a display device. The screens may then be viewed by the terminal operator either in or out of sequence and as many times as desired.

videotex (1) A service that provides interactive exchange of alphanumeric and graphic information, over common carrier facilities to the general public. The user must have a special display terminal or adapted television set. Synonymous with interactive videography, viewdata. (T) (2) A system that provides two-way interactive information services, including the exchange of alphanumeric and graphic information, over common carrier facilities to a mass consumer market using modified TV displays with special decoders and modems. See also teletext.

Note: Several versions of videotex have been developed outside the US; for example, in Canada Telidon, in Germany Bildschirmtext, in Japan Captain, and in the U.K. Prestel.

view (1) In an information resource dictionary, the combination of a variation name and revision number that is used as a component of an access name or of a descriptive name. (A) (2) In SQL, an alternative representation of data from one or more tables. A view can include all or some of the columns contained in the table or tables on which it is defined. (3) In the OS/2 operating system, the appearance of the contents of an open object. (4) In IBM network management products, a graphical representation of a

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VIRTUAL ENVIRONMENT DISPLAY SYSTEM

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ABSTRACT

A head-mounted, wide-angle, stereoscopic display system controlled by operator position, voice and gesture has been developed for use as a multipurpose interface environment. The system provides a multisensory, interactive display environment in which a user can virtually explore a 360-degree synthesized or remotely sensed environment and can viscerally interact with its components. Primary applications of the system are in telerobotics, management of large-scale integrated information systems, and human factors research. System configuration, application scenarios, and research directions are described.

RESEARCH OBJECTIVES

Recent changes in requirements for human interaction with increasingly autonomous and semi-autonomous intelligent systems are exemplified in cockpit automation of high-performance aircraft and in development of automation and robotics technology for Space Station [1,2]. Although the long term goal of the automated space station and associated telerobotic systems is virtually autonomous operation, it is generally recognized that human operators will continue to monitor and supervise the systems under normal operations and to intervene under degraded modes, while also monitoring other space station and mission related tasks. And, although the astronaut crew will be less in number, less specialized and from more diverse backgrounds, their attentions will be divided among many disparate tasks; The projected number of workstations in the Space Station task environment is near 40, with workstation panels numbering over 200, and control-display elements at 3,000 [3]. Performance in such task environments will require major functional advances in operator interface configurations and performance capabilities.

The primary objective of this research is to develop a multipurpose, multimodal operator interface to facilitate natural interaction with complex operational tasks and to augment operator situational awareness of large-scale autonomous and semi-autonomous integrated systems. The system should specifically provide a uniform interface for multiple task supervision, be reconfigurable for varying levels of operator skill, training and preference, and have an operator interface configuration that features human matched displays and controls for transparent, natural system interaction and reduced training requirements.

In the Aerospace Human Factors Research Division of NASA's Ames Research Center, an interactive virtual environment display system controlled by operator position, voice and gesture has been developed to aid in generation and evaluation of advanced data display and management concepts for operator interface design. As a low-cost, multipurpose simulation device, this variable interface configuration allows an operator to virtually explore a 360-degree synthesized or remotely sensed environment and viscerally interact with its components. Application areas of the virtual interface environment research are focused on: development of workstations for telerobotics and telepresence control; workstations for supervision and management of large-scale integrated information systems; and human factors research.

SYSTEM CONFIGURATION

The current virtual environment display system consists of: a wide-angle stereoscopic display unit, glove-like devices for multiple degree-of-freedom tactile input, connected speech recognition technology, 3D sound cueing and speech-synthesis technology, gesture tracking devices, and computer graphic and video image generation equipment.

Displays

The prototype display unit is helmet-mounted and consists of medium resolution, monochromatic liquid crystal display screens presented to each eye of the user through wide-angle optics (see Fig.1). The effective field of view for each eye is 120 degrees for horizontal and vertical with a common binocular field of up to 90 degrees. The prototype LCD screens measure 2.7-inches diagonally and do not yet fill the field of view completely (see Fig.2). Near term developments will replace these displays with 4-inch diagonal, high resolution LCD screens. For stereoscopic image presentation, binocular parallax cues are derived from horizontally disparate viewpoints of a three-dimensional computer image database or from a pair of horizontally disparate remote video cameras. Calibration for differences in interocular distance of different users is controlled by electronically shifting the displayed images to the correct separation.

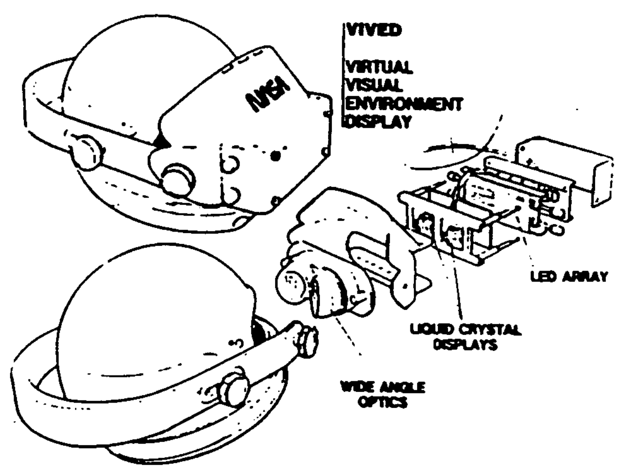

Fig.1 Protoype virtual environment display system. Principal investigators: M.McGreevy & J.Humphries, NASA/Ames, 1985.

As the user changes viewpoint of the displayed scene, head motion is tracked in real time by a helmet-mounted, 6 degree-of-freedom tracking device. The derived position and orientation data is used to update the displayed stereo images in coordination with the users activity. The resulting imagery contains full motion parallax and motion perspective information in response to the users movement through the virtual environment. The imagery appears to completely surround the user in 3-space and enables the operator to explore virtual objects and environments in real time and from multiple viewpoints (see Fig. 3).

The liquid crystal display technology is used to meet design requirements for size, weight, power, safety and low cost (see Fig. 4). Imagery displayed on the screens is a NTSC standard video signal generated by computer, remote video cameras, or a combination of these input media with other video sources such as optical video disk. Both commercial and custom video mixing and switching equipment is used to overlay the different image sources on a common background to provide multiple, interchangeable windows of information to the operator.

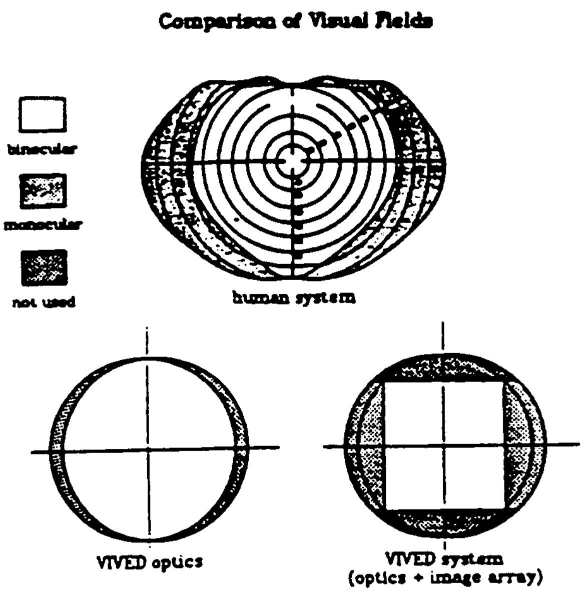

Fig.2 Comparison of binocular field of view in the human visual system, the effective field of view of the virtual environment display system optics, and the field of view as limited by LCD screen size.

Fig.4 Transmissive liquid crystal display screen used in the virtual environment display system.

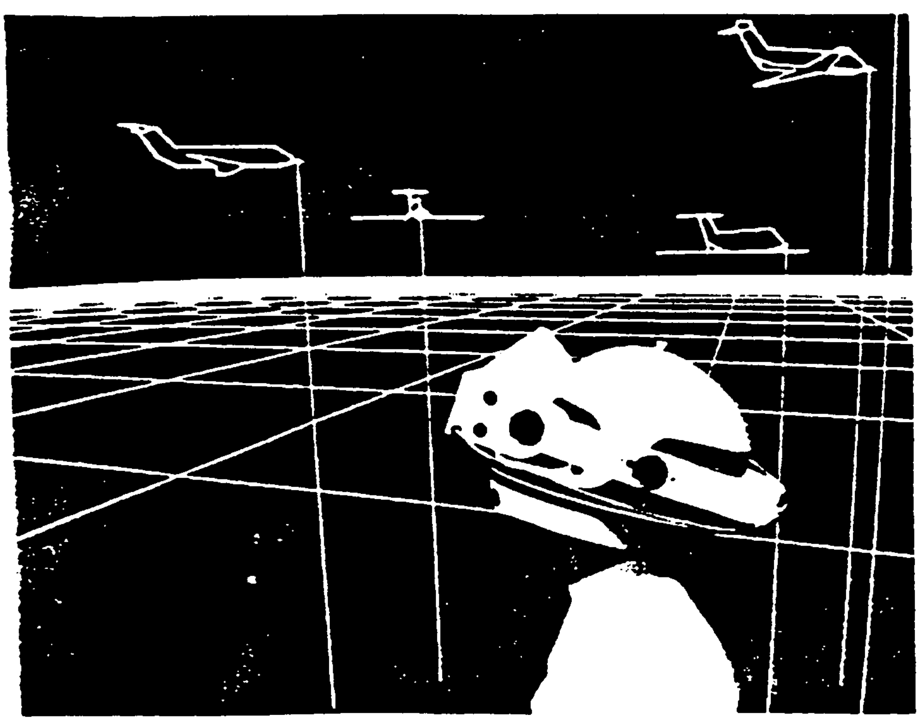

Fig.3 Imagery displayed in the virtual environment appears to completely surround the user in 3-space and enables the operator to explore virtual objects and environments in real time and from multiple viewpoints.

An alternative head-mounted display unit has also been developed with identical optical and display capabilities to the original helmet prototype (see Fig. 5). This configuration is smaller and lighter in weight and is designed for easier replication. The new display package is also implemented in a movable arm-mounted, workstation configuration for evaluation in design and engineering applications (see Fig. 6).

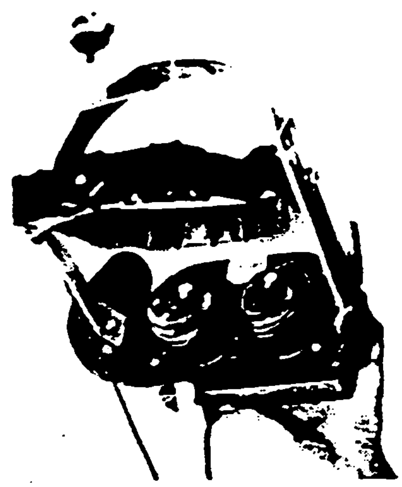

Fig.5 Light-weight, head-mounted display unit with wide-angle optics and LCD displays.

In addition to the visual display, sound display technologies are used in this system to provide additional task, system status and navigation information to the operator and to enhance overall situational awareness. Commercially available speech-synthesis technology with unlimited vocabulary capability is used primarily for voice report requirements and acknowledgement of system input. Also, three-dimensional sound technology is used to provide spatially correspondent sound cues for objects or events both within or outside of the operator's immediate field of view. Delivered through headphones, the prototype 3D sound equipment generates sound cues that are perceived outside of the head and localised at some discrete direction and distance in 3-space around the user. By updating the position information of the samples in real time, the localized sound cues maintain their spatial positions as the user interacts with the virtual environment.

Display Interaction

Visceral interaction with the virtual environment surrounding the user is through speech and gesture input technologies. The system includes commercially available connected speech-recognition technology that allows the user to give system commands in a natural, conversational format in contrast to highly constrained discrete word recognition systems or keyboard input. Typical speech mediated interactions are requests for display/report of system status, instructions for supervisory control tasks, and verbal commands to change interface mode or configuration.

For tactile interaction with the displayed three dimensional environment, the user wears lightweight glove-like devices that transmit data-records of arm, hand and finger shape and position to a host computer. The gloves are instrumented with flex-sensing devices at each finger joint, between fingers and across the palm of the hand (see Fig.7). Motion tracking sensors like that described for tracking head motion are mounted on each glove to transmit position and orientation of the hands and arms to the host system (see Fig. 8). One application of this technology is to provide a three-dimensional cursor in the displayed environment. And, in coordination with connected speech recognition technology, the hand and arm gesture information is used to effect indicated gestures in the synthesised or remote environment (e.g. control of robotic arms and

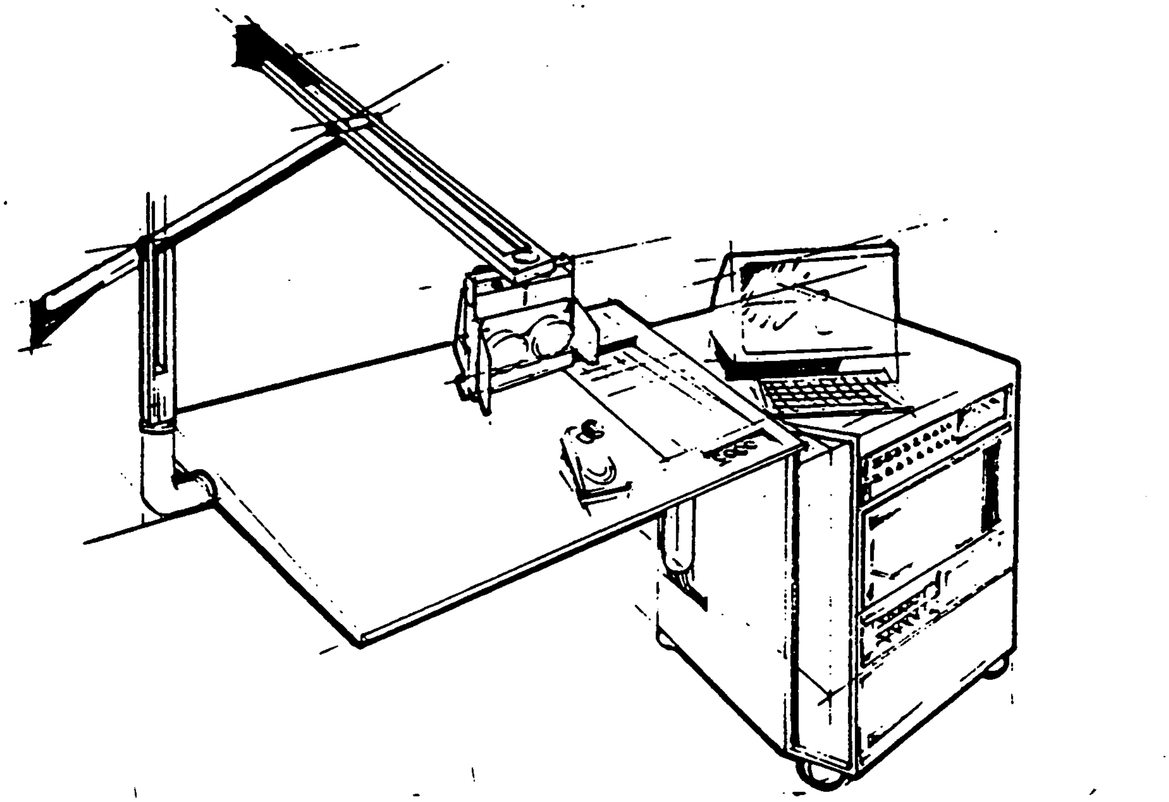

Fig.6 Virtual environment workstation configuration.

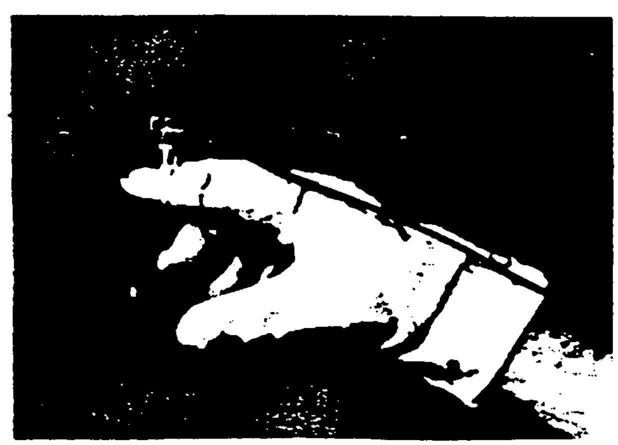

Fig.7 Tactile input glove illustrating flex-sensors, interface chip and position/orientation sensor.

Fig.8 Tactile input glove with position and orientation tracker.

end-effectors, and associated control of auxiliary camera positions). Current implementations of this research include a three-dimensional graphic database of an articulated hand that, in the display environment, is spatially correspondent with the viewer's real hand and is directly controlled by the instrumented glove device (see Fig. 9). With this capability, the operator can pick-up and manipulate virtual objects that appear in the surrounding virtual environment. Similarly, in the virtual data management environment, multiple windows of information and simulated control panels are positioned, sized and activated by manipulating the virtual objects in 3-space (see Figs. 10 and 12).

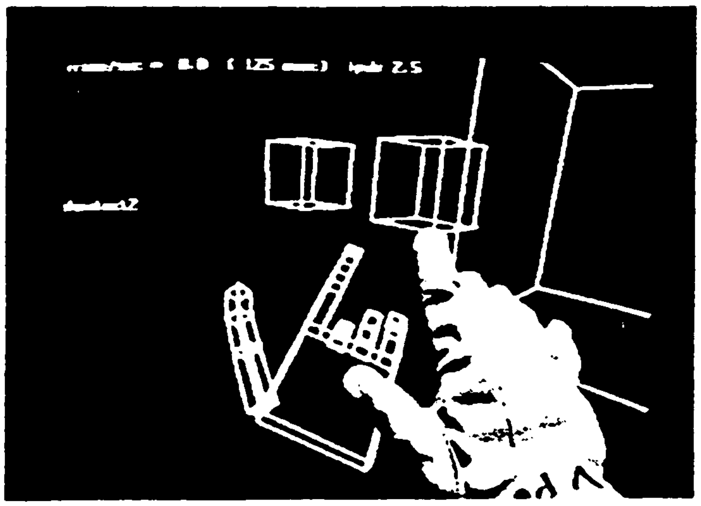

Fig.9 3D graphic virtual objects and articulated hand directly controlled by DataGlove.

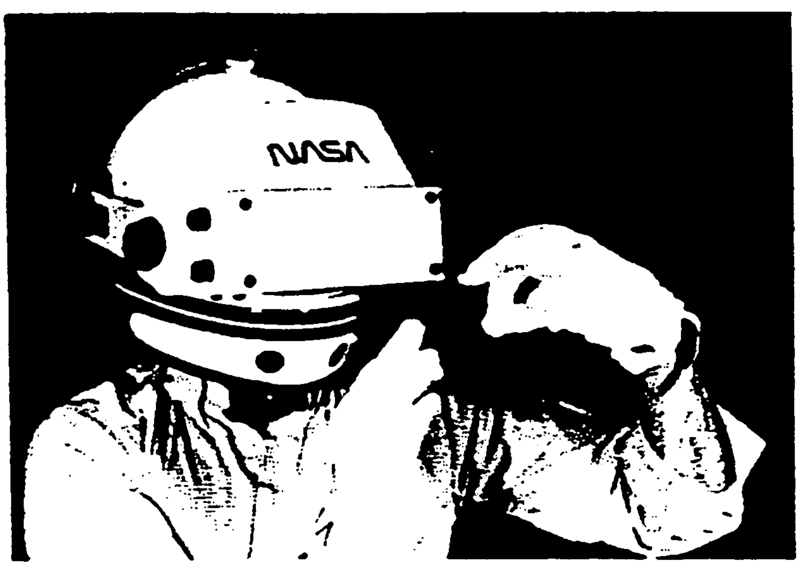

Fig.10 Speech and gesture interaction in the virtual environment display system.

VIRTUAL INTERFACE APPLICATIONS

Supporting Research

Over the past two decades, results of various specialized research programs on advanced concepts for human-machine interaction have gradually made possible the development of flexible, multisensory, interactive display and control environments that can be applied to current operator interface design requirements.

In the mid-1970's, scientists at Bell Laboratories developed a reconfigurable keyboard console in which computer generated labels are optically superimposed onto a two-dimensional array of pushbuttons and rapidly changed as the task requires [4]. At MIT, this concept was later extended to a limited three-dimensional virtual workspace in which a user interactively manipulates 3D graphical objects that are spatially correspondent with hand position [5]. A key concept in each project is the use of interactive computer graphics to create a virtual workstation environment.

During the same time period, researchers at MIT developed a prototype room-sized human-machine interface environment with wall-sized display and octophonic sound surrounding the user [6]. Rather than keyboard input, interaction is through speech, gesture and touch sensitive displays [7]. Emphasis is on creating a highly visual and personalized interface environment in which information access and manipulation is facilitated by discrete spatial organization and natural interaction [8].

Specialized requirements for display environments that are closely matched to human vision capabilities have resulted in the development of head-mounted and head-coupled display concepts. Initial research at Philco developed a head-mounted CRT for viewing a remote television camera coupled to operator head motion [9]. Later work at the University of Utah developed a binocular head-mounted display that superimposes computer generated virtual objects into the real environment of the user [10]. Numerous research efforts continue to explore the perceptual and technological requirements for simulation of presence in remote or synthesized environments [11],[12],[13].

The virtual environment display system developed at NASA Ames combines many of the concepts and performance capabilities of the human-machine interface developments described above in one integrated configuration. Following are descriptions of specific task environments for which this interface will be evaluated.

Telerobotics

Control of autonomous and semi-autonomous telerobotic devices and vehicles requires an interface configuration that allows variable modes of operator interaction ranging from high-level, supervisory control of multiple independent systems to highly interactive, kinaesthetic coupling between operator and remote system. An appropriate interface for supervisory control modes will provide the operator with multiple viewpoints of the remote task environment in a multi-modal display format that can be easily distributed and reconfigured according to changing task priorities. For remote operations that cannot be performed autonomously, the interface will need capability to quickly switch to interactive control. In this telepresence mode, the operator is provided with a sufficient quantity and quality of sensory feedback to approximate actual presence at the remote task site.

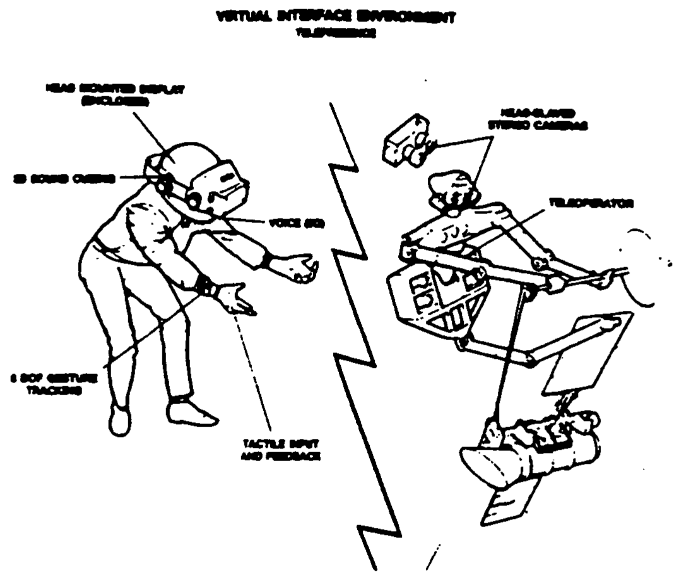

Fig.11 Virtual interface environment for telerobot control.

The virtual environment display system is currently used to interact with a simulated telerobotic task environment. The system operator can call up multiple images of the remote task environment that represent viewpoints from free-flying or telerobot-mounted camera platforms. Three-dimensional sound cues give distance and direction information for proximate objects and events. Switching to telepresence control mode, the operator's wide-angle, stereoscopic display is directly linked to the telerobot 3D camera system for precise viewpoint control. Using the tactile input glove technology and speech commands, the operator directly controls the robot arm and dexterous end effector which appear to be spatially correspondent with his own arm (see Figs.9 and 11).

Current experimental research includes system calibration for orthoscopic image display, evaluation of operator performance in teleoperation placement tasks, and analysis of perceived localization of synthesized sound sources in 3-space.

Information Management

Similar to interface requirements for supervisory control of telerobotic systems, the operator interface for large-scale integrated information systems such as Space Station will also require a range of interaction modalities for operator intervention in the case of system degradation or conflicts in resource allocation. Efficient supervision of these automated systems will depend on highly graphic, multi-dimensional status representations of the numerous sub-systems in a format that can be easily monitored in parallel with other mission related tasks such as planning and scheduling, telerobot supervision, and communication activities. In the event of system conflict or malfunction, the interface environment should enable natural interaction with muti-modal, knowledge-based warning and advisory systems.

Advanced data display and management concepts for this task environment are being developed with the virtual environment display technology. Current investigations include use of the system to create a display environment in which data manipulation and system monitoring tasks are organized in virtual display space around the operator (see Fig. 5). Through speech and gesture interaction with the virtual display, the operator can rapidly call up or delete information windows and reposition them in 3-space. Three-dimensional sound cues and speech-synthesis

technologies are used to enhance the operators overall situational awareness of the virtual data environment. The system also has the capability to display reconfigurable, virtual control panels that respond to glove-like tactile input devices worn by the operator.

Major research issues include development of multi-modal data access and manipulation guidelines; concepts for multi-dimensional, graphic representation of knowledge-based information systems; and definition of interface configurations for shared workspace environments in collaborative systems management.

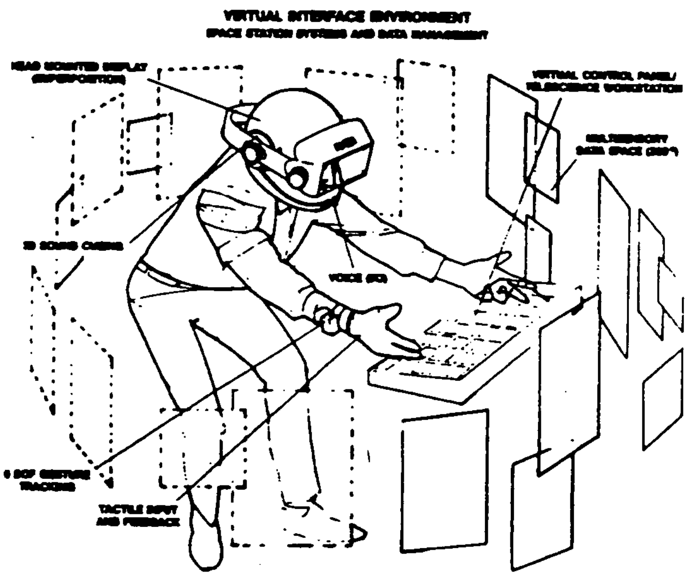

Fig.12 Virtual interface environment for management of large-scale integrated information systems.

Human Factors Research

An additional research objective includes use of this display system as a low-cost, three-dimensional simulation facility to synthesize interactive test environments for aerospace human factors research in such areas as: spatial habitability research, rapid prototyping of display and workstation configurations, research on effective transfer of spatial information, and spatial cognition research on multisensory integration.

DISCUSSION

Unlike most technology for 360-degree visual simulation environments, the virtual environment display system does not make use of large, expensive, special purpose projection configurations. The described system is portable and low-cost without large space and equipment requirements. In comparison to other research efforts in head-mounted displays, this system is unique in presenting a stereoscopic image that closely matches human binocular vision capabilities and in its configuration with state-of-the-art speech and tactile input technology.

The systems' capabilities for providing a highly graphical, uniform interface for varying task environments and level of interaction is critical to reduce operator workload and training requirements and to increase productivity. Use of muti-modal input channels and augmentation of visual displays provides unobtrusive redundancy for increased accuracy and efficiency in human-

machine interaction. Also, multiple viewpoint presentation of task related information in a 360-degree, dynamic stereoscopic display will increase situational awareness and effectiveness in monitoring cognitively demanding spatial tasks such as construction and proximity operations or spatial representations of knowledge-based systems and activities.

As a research tool, the virtual environment display system follows many research efforts to develop operator control stations for teleoperation and telepresence but has a unique configuration to investigate natural, multisensory interaction with complex operational tasks. As an interface for data management tasks, this system is a continuation of recent research in multimodal, natural input technology and concentrates on development of a true three-dimensional, graphical interface environment that can be easily reconfigured for idiosyncratic requirements; In addition to specific aerospace and industrial applications discussed above, the virtual environment display system may find further application in such areas as education, architectural and engineering design simulation, medical imaging and microsurgical procedures, or entertainment and recreation.

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